

CLAIMS

1. A lamination-type piezoelectric element comprising: a ceramic laminated body in which ceramic layers and inner electrode layers are alternately laminated on each other; and a pair of outer electrodes respectively joined to a pair of joining faces formed on an outer circumferential face of the ceramic laminated body, wherein

an outer circumferential groove portion coming into contact with an outer circumferential end portion of at least some part of the inner electrode layers is formed at least on the joining faces on the outer circumferential face of the ceramic laminated body, the outer circumferential groove portion has at least one dent portion which recesses inward from the outer circumferential face of the ceramic laminated body, a shape of the dent portion itself or shapes of a plurality of dent portions connected to each other are formed into a belt-shape, the outer circumferential groove portion also has at least one or more protruding portions protruding from the periphery inside the dent portion or the outer circumferential groove portion also has a protruding portion protruding from the dent portion being arranged between the dent portions being adjacent to each other, and

at least one of an insulating portion made of insulating material or a conductive portion made of conductive material is formed in the outer circumferential groove portion so that the dent portion can be embedded and the protruding portion can be covered.

2. A lamination-type piezoelectric element according to claim 1, wherein the outer circumferential groove portion is formed coming into contact with the outer circumferential end portion of every other inner electrode layer of the joining faces,

concerning the inner electrode layer, on

one joining face of which the outer circumferential groove portion is formed, the outer circumferential groove portion is not formed on the other joining face, concerning the inner electrode layer, on one joining face of which the outer circumferential groove portion is not formed, the outer circumferential groove portion is formed on the other joining face, and

the insulating portion is formed in the outer circumferential groove portion concerned.

3. A lamination-type piezoelectric element according to claim 1, wherein the outer circumferential groove portions are formed coming into contact with the outer circumferential end portions of all of the inner electrode layers on the joining face,

the insulating portions and the conductive portions are alternately formed on the outer circumferential groove portions formed on the joining face,

the inner electrode layer coming into contact with the insulating portion on one joining face comes into contact with the conductive portion on the other joining face, and the inner electrode layer coming into contact with the conductive portion on one joining face comes into contact with the insulating portion on the other joining face.

4. A lamination-type piezoelectric element according to claim 1, wherein the outer circumferential groove portion coming into contact with the outer circumferential end portion of the inner electrode layer is formed on the entire outer circumferential face except the joining face of the ceramic laminated body, and

the insulating portion is formed in the outer circumferential groove portion.

5. A lamination-type piezoelectric element according to claim 1, wherein a plurality of bowl-shaped machined holes, the diameter of which is reduced as the holes go deeper, are formed in the dent portion,

peripheral edge portions of the holes, which are adjacent to each other, overlap with each other, and the protruding portion is formed between the holes, which are adjacent to each other, in such a manner that the protruding portion is protruding.

6. A lamination-type piezoelectric element according to claim 1, wherein the shape of the dent portion is formed into a bowl-shape, the diameter of which is reduced as the dent portion goes deeper, a plurality of the dent portions are formed at discrete positions arranged in a belt-shape, and the protrusion is formed between the dent portions which are independently arranged and adjacent to each other.

7. A lamination-type piezoelectric element according to claim 1, wherein the outer circumferential end portion of the inner electrode layer is protruded outward on the bottom face of the dent portion.

8. A lamination-type piezoelectric element according to claim 7, wherein a protruding distance of the outer circumferential end portion of the inner electrode layer is not less than the thickness of the inner electrode layer.

9. A method of manufacturing a lamination-type piezoelectric element which includes a ceramic laminated body, in which ceramic layers and inner electrode layers are alternately laminated on each other, and also includes a pair of outer electrodes respectively joined to a pair of joining faces formed on an outer circumferential face of the ceramic laminated body, the method of manufacturing the lamination-type piezoelectric element comprising:

a laminated body forming step of forming the ceramic laminated body;

a groove forming step of forming a dent portion coming into contact with an outer circumferential end portion of at least some part of the inner electrode layers by irradiating a laser beam onto at least the

joining faces on the outer circumferential face of the ceramic laminated body so as to form an outer circumferential groove portion, the shape of the recess portion of which is formed into a belt-shape, or the shapes of a plurality of recess portions connected with each other of which are formed into a belt-shape; and

an embedding step of forming at least one of an insulating portion made of insulating material and a conductive portion made of conductive material in the outer circumferential groove portion.

10. A method of manufacturing a lamination-type piezoelectric element according to claim 9, wherein the outer circumferential groove portion having at least one protruding portion protruding from the periphery inside the dent portion or having at least one protruding portion protruding from the dent portion, arranged between the dent portions adjacent to each other is formed by adjusting an irradiating condition of the laser beam in the groove forming step, and

the dent portion is embedded so as to cover the protruding portion by forming at least one of an insulating portion made of insulating material and a conductive portion made of conductive material into the outer circumferential groove portion in the embedding step.

11. A method of manufacturing a lamination-type piezoelectric element according to claim 10, wherein a laser beam is irradiated so that an intensity of irradiating energy, which irradiates at a position where the protruding portion is to be formed, can be lower than an intensity of irradiating energy, which irradiates at a position adjacent to the position where the protruding portion, which protrudes in the direction of the normal line on the outer circumferential face of the ceramic laminated body, is to be formed, in the groove forming step.

12. A method of manufacturing a lamination-type

piezoelectric element according to claim 10, wherein the belt-shaped dent portion extending zigzag is formed when the laser beam irradiating position is moved zigzag along the outer circumferential end portion of the inner electrode layer in the groove forming step, and the laser beam is irradiated so that the protruding portion protruding in the laminating direction of the ceramic laminated body can be formed in a bent portion of the dent portion.

10           13. A method of manufacturing a lamination-type piezoelectric element according to claim 10, wherein a method of manufacturing a lamination-type piezoelectric element, in which a laser beam is irradiated so that an intensity of irradiating energy, which irradiates at a position where the protruding portion is to be formed, can be lower than an intensity of irradiating energy, which irradiates at a position adjacent to the position where the protruding portion, which protrudes in the direction of the normal line on the outer circumferential face of the ceramic laminated body, is to be formed in the groove forming step, and a method of manufacturing a lamination-type piezoelectric element according, in which the belt-shaped dent portion extending zigzag is formed when the laser beam irradiating position is moved zigzag along the outer circumferential end portion of the inner electrode layer in the groove forming step and the laser beam is irradiated so that the protruding portion protruding in the laminating direction of the ceramic laminated body can be formed in a bent portion of the dent portion, are combined with each other and the laser beam is irradiated so as to form the protruding portion.

30           14. A method of manufacturing a lamination-type piezoelectric element according to claim 10, wherein the laser beam is irradiated at discrete positions distributed along the inner electrode layer by ON-OFF control in which irradiation and non-irradiation of the laser beam are repeated while a position at which the

laser beam is to be irradiated is being continuously moved along the inner electrode layer of the ceramic laminated body.

5        15. A method of manufacturing a lamination-type piezoelectric element according to claim 11, wherein the laser beam is a beam generated by a CO<sub>2</sub> laser.

10       16. A method of manufacturing a lamination-type piezoelectric element according to claim 11, wherein the wave-length of the laser beam is not less than 157 nm and not more than 10600 nm.

17. A method of manufacturing a lamination-type piezoelectric element according to claim 11, wherein the diameter of an irradiation spot of the laser beam is not more than 120  $\mu$ m.

15       18. A method of manufacturing a lamination-type piezoelectric element according to claim 11, wherein stabilization baking of the ceramic laminated body is executed after the laser beam is irradiated and the dent portion is formed.